PERIDOTITES AND CORUNDUM

[AUTHOR'S ABSTRACT]

Corundum and the Basic Magnesian Rocks of Western North Carolina. By J. VOLNEY LEWIS. *Bulletin*, North Carolina Geological Survey, No. 11, 1896.

Corundum and the Peridotites of Western North Carolina. By JOSEPH HYDE PRATT and JOSEPH VOLNEY LEWIS. *Reports*, North Carolina Geological Survey, Vol. I, 1906.

Corundum and its Occurrence and Distribution in the United States. By JOSEPH HYDE PRATT. *Bulletin*, U. S. Geological Survey No. 269, 1906.

Although a decade elapsed between the appearance of the first and the last two of the above publications they are so intimately connected that they should be reviewed together.

The first is a record of the distribution and the modes of occurrence of the peridotites and the associated corundum deposits of western North Carolina, with briefer descriptions of similar occurrences throughout the eastern crystalline belt of the continent.

The second is an elaboration and revision of the first, particularly as regards the petrography of the peridotites and the mineralogy of corundum and the associated minerals. It differs essentially from this, however, in that it takes up quite fully the theoretical questions of origin and relationships of the various rocks and minerals concerned.

The third publication listed above, although bearing the name of but one of the authors, is essentially a rearrangement of the subject-matter of the other two, with the omission of most of the petrography and a slight enlargement upon important localities outside of North Carolina. It is, in the main, a reprint, both in text and illustrations, although this fact is nowhere indicated. A footnote on p. 28 merely refers to the North Carolina report, without naming the authors or intimating that the text is the same. Joint authorship for four pages of text is acknowledged, however, in a footnote on p. 62, and the reader is left to infer that the remainder is the work of the author whose name appears on the title-page.

This review is therefore chiefly concerned with the second, *Corundum and the Peridotites of Western North Carolina*, which constitutes the first volume of a new series of reports of the North Carolina Geological Survey. It is a volume of 464 pages, is illustrated by 45 plates and 35 figures in the

text, and is in many respects a work of much broader scope than the title indicates.

As stated in the preface, the petrography was chiefly the work of Lewis, and the mineralogy was in charge of Pratt. Other portions of the work are the result of collaboration, and there was a constant interchange of all manuscript for criticism and revision. The individual work of the authors was done, for the most part, at different times and places, each working independently. Notwithstanding this fact, each was led to essentially the same conclusions in regard to the origin and relations of both the peridotites and corundum. Concerning corundum in the basic magnesian rocks, very similar, and in some respects supplementary, hypotheses were deduced by the one from a study of the mines in the peridotites and by the other from the petrology of the corundum-bearing amphibolites and anorthosites. (Cf. pp. 144 and 344.)

A brief sketch of the geology of the state is given in chapter i, with a somewhat fuller account of the belt of gneisses, granites, and schists constituting the rugged mountainous section in which the peridotites and the corundum deposits occur.

Chapter ii deals with the peridotites and the associated basic magnesian rocks. These include four varieties of peridotite, four pyroxenites, four gabbroic rocks, an amphibolite, and three diorites. These are chiefly well-known types. An exception is the pyroxenite composed of the orthorhombic pyroxene, enstatite. This rock occurs somewhat commonly throughout the region, and forms many masses of considerable extent. The name *enstatolite* is proposed for this type, in conformity with the terms "bronzitite" and "hypersthenite." All of these rocks are shown to be a part of the great series of basic magnesian rocks which extends throughout the whole length of the eastern crystalline belt from central Alabama to the Maritime Provinces of Quebec, and again reappears in Newfoundland. Together they constitute a petrologic unit of remarkable persistence and uniformity of characters and association.

Maps show the distribution and relations of these rocks to the crystallines in eastern North America and in western North Carolina besides several detailed maps of portions of the belt of particular interest. The contoured geological map of western North Carolina (Plate II) is the largest and most detailed yet published of this region. The scale is eight miles to the inch and the base is printed in three colors. On this the pre-Cambrian gneisses and schists and the Cambrian (?) metamorphic sediments are represented by tints, while the peridotite dikes and localities of corundum, chromite, and asbestos are shown in bright red.

Following the descriptions of these rocks throughout the Appalachian region, the distribution and petrographic characters are given in detail for western North Carolina. Sixty photomicrographs illustrate the mineralogic and structural varieties and modes of alteration of the rocks described, and their chemical relations are shown by Hobbs-Brögger diagrams.

Two classes of secondary rocks are described: namely, (1) the mechanically derived schists, gneisses, and gabbrodiorites, and (2) a series of hydrous alteration products, chiefly steatite, chloritite (chlorite-rock), and serpentine.

The vast majority of occurrences, while more or less altered, are essentially fresh primary rocks. This is especially true of the pure olivine-rock, dunite, which is the most common type. Steatite and chloritite are pretty widely found, but serpentine is practically confined to a region within fifteen miles of the French Broad River. Even here remnants of unaltered peridotite are abundant.

The various modes of alteration and decomposition are described in chapter iv. Five distinct processes are recognized, and are designated, except the first, by the prevailing product; namely, (1) weathering, (2) serpentinization, (3) steatitization, (4) chloritization, (5) amphibolization. All of these processes occur more or less together over wide areas, but one or another usually greatly predominates. Hence various areas are characterized by ocherous weathering products or by the abundance of one of the minerals, serpentine, talc, chlorite, and amphibole, with smaller proportions of the others.

The long-vexed question of the origin of the peridotites is discussed in chapter v. A historical sketch shows the kaleidoscopic variety of opinions and hypotheses that have been advanced to account for these rocks since 1875, the date of Professor Kerr's first report on this region. By various authors they have been regarded as unaltered sediments, metamorphic sediments, chemical deposits, metasomatized limestones and schists, and as igneous intrusions. Opinions have been divided chiefly, however, into two groups, corresponding closely to the old Neptunian and Plutonic schools of geology. The strong modern tendency toward the igneous theory of origin is clearly shown, and the correctness of this view is abundantly substantiated by this report. The data presented on this point are grouped under five heads, as follows: (1) mineralogic characters, (2) microscopic characters, (3) gross structures, (4) modes of occurrence, (5) relations to the gneisses and schists.

In the discussion of the general petrology of the basic magnesian rocks, the genetic unity of the series throughout the eastern crystalline belt is

strongly emphasized. It is noteworthy that a closely similar association of rock types is found in almost every peridotite locality, although some one usually preponderates in every case. Thus peridotites, particularly dunite, prevail in North Carolina and Quebec, pyroxenites in Pennsylvania, while gabbros are abundant in Delaware and parts of Maryland. The types represented in the various regions, however, are almost identical, and the petrology is closely similar, except in the relative abundance of the various types and in mode and degree of alteration.

Two generations of corundum are recognized. The greater part, including all deposits of commercial value, belongs to the first generation and represents the excess of alumina in the original magma. Another part, occurring in microscopic grains, is an excess of alumina arising from the corrosion of anorthite crystals by the still molten magma. This process has produced sheaths of minerals which form the *corrosion mantles*, so greatly developed in some localities, and in other cases entirely replacing the anorthite, or the corroding magma, as the case may be, by nestlike aggregates of intermediate silicates.

In discussing the age of the peridotites (pp. 152–59), it is recalled that until recently it has been the custom of geologists to refer the whole of the Appalachian crystalline belt to the Archaean, or at least to pre-Cambrian. Recent work in several regions makes it impossible longer to accept these old correlations without other than merely lithologic evidence. Tables are given showing possible correlations of the crystallines in areas recently investigated, from North Carolina to Massachusetts and the Green Mountains, and summaries are given of the various conclusions as to age arrived at by geologists in different parts of the field. The conclusions of the authors of this report may be briefly stated as follows: The intrusion of the peridotites was probably contemporaneous, or practically so, for the whole region under consideration, from Alabama to Newfoundland. These rocks now form a belt of remarkable unity through a region of great orogenic disturbance and intense metamorphism. These facts, together with the geologic relations that have been deciphered in some northern portions of the belt, suggest the hypothesis that the chief period of intrusion may be correlated with the folding movements of closing Ordovician. The peridotite belt doubtless marks the axis of most intense disturbance. The later orogenic movements, at the close of the Carboniferous, produced the widespread lamination of these rocks, and probably gave occasion for additional minor intrusions. Much painstaking work yet remains to be done, however, in many parts of the field, before any hypothesis concerning the age of the peridotites can be satisfactorily established.

Chapter v closes with a discussion of the secondary rocks. The authors undertake to trace back to their original types the various laminated and hydrated derivatives. The question arises whether the amphibolites, diorites, hornblende-schists, and hornblende-gneisses, may not themselves have been derived from corresponding pyroxenic types, such as occur in the Maryland and Delaware gabbro areas. The fact that undoubted gabbrodiorites do occur in portions of the belt in North Carolina makes it quite probable that many, if not all, of these amphiboliferous types have had a like origin.

Chapter vi deals with the mineralogy and technology of corundum, including its crystallography, its physical and chemical properties, its applications in the arts, and an outline of the process of manufacture of the several types of corundum and emery wheels on the market.

Chapter vii, on modes of occurrence, shows corundum to be a constituent of a remarkable number and variety of rocks, including nineteen igneous types, nine metamorphic, and one unaltered sedimentary. These corundum-bearing rocks are distributed as follows:

CORUNDUM-BEARING IGNEOUS ROCKS

North Carolina	*Other American Localities*	*Elsewhere*
Peridotite	Granite	Kyschtymite
Pyroxenite	Syenite	Diorite
Amphibolite	Nephelite-syenite	Tonalite
Anorthosite	Plumasite	Gabbro
Pegmatite	Norite	Trachyte
	Andesite	Quartz-porphyry
	Monchiquite	Basalt

CORUNDUM-BEARING METAMORPHIC ROCKS

Serpentine	Crystalline limestone	Corundum-schist
Gneiss		Corundum-porphyroid
Mica-schist		Graphite
Quartz-schist		Igneous contacts
Amphibole-schist		Inclusions
Chlorite-schist		

OTHER CORUNDUM-BEARING ROCKS

Alluvial gravels
Undetermined (emery)

The American occurrences, particularly those of North Carolina, are described in detail and compared with similar deposits, when known, in other parts of the world. Those of chief commercial importance in North Carolina are in peridotites, and to a less extent in amphibolites and pyroxenites. The gravel deposits are of interest on account of the corundum gems (rubies) and the garnet gems (rhodolite) that occur in some of them.

In peridotites corundum occurs chiefly (1) in peripheral or border

"veins" which skirt along the borders of many of the massive outcrops, and (2) in interior "veins," extending from the borders toward the center of the peridotite mass. The mode is similar in the pyroxenites and in certain amphibolites. In other amphibolites, the corundum is irregularly disseminated in grains, plates, and nodular aggregates throughout large masses of the rock. Corundiferous pegmatite forms small dikes accompanying and penetrating both peridotites and amphibolites in some localities. The corundum-bearing serpentines, amphibolites, and chlorite-schists are simply derivatives of the foregoing types, with more or less dynamic and chemical alteration and rearrangement. Corundum-bearing gneisses and mica schists, which sometimes pass into quartz-schists, have no relation with the peridotites, although occurring in the same region and sometimes near the outcrops of these rocks. The chief localities of corundiferous peridotites, gneisses, and schists are in Clay, Macon, and Jackson Counties, North Carolina, near the southwestern corner of the state. Scattering occurrences in amphibolites and gneisses are also found east of the mountains, particularly in Iredell County.

The distribution of corundum is considered in chapter viii. First the Appalachian localities are described, including Alabama, Georgia, South Carolina, North Carolina, Virginia, Pennsylvania, New Jersey, New York, Connecticut, and Massachusetts. Occurrences in Montana, Colorado, and California are also described, as well as the corundum and emery deposits of Canada, India, Turkey, and the Grecian islands. North Carolina localities are described in detail, by counties.

The alterations of corundum and the minerals associated with it are described in chapter ix. The list of associated minerals from North Carolina localities includes 62 species, each of which is described, with its mode of occurrence and its relations to the corundum. Chemical analyses and crystallographic characters of many are also given. From other American and foreign localities the number of associated minerals is increased to seventy-four.

The origin of corundum is considered in chapter x. The discussion is prefaced by an account of the artificial production of the mineral and a summary of the various hypotheses that have been advanced during the last twenty-five years. From a consideration of field relations and the later experiments with silicate magmas, the conclusion is reached that the corundum of the peridotites was held in solution in the magma when it was injected into the gneisses, and that it crystallized out among the first minerals formed, as the mass began to solidify. Corundum in quartz-schists and gneisses, on the other hand, is the result of metamorphism of

sandstones and shales rich in alumina, which was probably in the form of bauxite.

Methods of prospecting, mining, and milling are described in chapter xi. It is prefaced by a historical sketch of corundum in the East and an account of discoveries and mining in the United States and Canada.

Chapter xii deals with the various other economic minerals of the peridotite belt—chromite, asbestos, genthite, serpentine, and limonite. Chromite in promising quantities has been found at a number of localities in North Carolina, particularly in Yancey and Jackson Counties. Asbestos (chrysotile) of good quality frequently occurs, but no mining has yet developed in North Carolina. The well-known Canadian deposits, however, are in the northward extension of this belt. The nickel ores (genthite and related silicates) occur widely, and are unquestionably derived from the decomposing peridotites, in the joints of which they are found. Serpentine in large bodies is a direct alteration product of the peridotites in North Carolina, but its occurrence is extremely limited, as compared with the abundance of the latter. Residual limonite beds have sometimes been formed from decomposing peridotites, and these have been utilized as iron ores in some portions of the belt in New York and Pennsylvania.

An appendix of twenty pages consists of a bibliography of American peridotites, corundum, and associated minerals. Copious references to both American and foreign literature are also given in footnotes throughout the report.

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Lower Paleozoic Formations in New Mexico. By C. H. GORDON and L. C. GRATON. (*American Journal of Science*, Vol. XXI, pp. 390–95, 1906.)

In *Science* for April 13, 1906, announcement was made of the discovery in Sierra and Grant counties, New Mexico, of formations belonging to the Cambrian, Ordovician, Silurian, and Devonian series. A more extended account of these formations by C. H. Gordon and L. C. Graton of the U. S. Geological Survey appeared in the *American Journal of Science* for May, 1906. A full account of the investigations upon which these announcements are based will appear in a forthcoming report of the U. S. Geological Survey, on the mining districts of New Mexico.

The Cambrian rocks consist of quartzites, sandstones, and shales, with occasional beds of limestone. They range in thickness from 50